# A TRANSIENT APPROACH TO THE SOLUTION OF A LINEAR SERVOMECHANISM BY AN EQUIVALENT NETWORK

BY

SHIH-PAI TUNG

B.S., National South-West Associated University, 1946
M.S., University of Illinois, 1949

## AN ABSTRACT OF A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
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# A TRANSIENT APPROACH TO THE SOLUTION OF A LINEAR SERVOMECHANISM BY AN EQUIVALENT NETWORK

The stability criterion for a dynamic system was given by Routh in 1877 and Hurwitz in 1895. Nevertheless, the precise location of the zeros of the characteristic equation cannot be immediately predicted although it may be known that they are in the left-hand side of the p-plane when the system is stable. In 1945, Wall developed a similar criterion by means of the continued fraction which can also be looked upon as the expression of the input impedance of a two terminal network which consists of a unit resistance connected in series with a pure reactive ladder structure in Cauer form. Therefore the complex angular frequency p, at which the input impedance is zero, will be the value of the zero of the characteristic equation. With this analogy on hand, it is easier to obtain the location of the zeros by experimental method as well as iterative process and graphical solution. But if the zeros are rather apart from each other, then first order approximation will give results with errors around ten percent.

Use of the equivalent network is made to study the synthesis problem. To illustrate the method, the effect on the location of zeros by varying time delay, gain constant and adding derivative or integral controls is discussed and can be summarized as follows:

(1) Increasing time delay decreases the absolute value of the real part of the zeros as well as the undamped angular frequency and vice versa.

(2) Increasing time delay by k times, meanwhile decreasing gain constant by k times, reduces the zeros of the new system by k times.

(3) Adding derivative control to the KG function corresponds to having some capacitors and inductors connected in

series or parallel to the elements of the equivalent network. Thus the effect on the location of the zeros depends upon how the network elements are varied. For a fourth order system, it has been found that adding one derivative control will make the system unstable while adding another derivative cotnrol will make the system stable.

(4) Adding ideal integral control tends to reduce the value of the network elements to negative values, thus causing instability.

Furthermore, the following relations have been established:

(5) The product of two consecutive network elements is related to the Hurwitz detreminant and the undamped angular frequency is related to the Hurwitz determinant. By equating these two relations it is found that the square of the undamped angular frequency is equal to the reciprocal of the product of the last two network elements. Thus the actual frequency of damped oscillation can be predicted when the dominant roots are known.

(6) When all the smaller time delays of a higher order system are decreased to zero except the largest one which is conceivably related to the dominant roots, the corresponding network elements remaining are the last two. Therefore it is reasonable to say that they are associated with the dominant roots when other roots are rather far apart.

Various examples as well as a procedure in the designing of a KG function with given location of zeros are included in this thesis to illustrate the application of the equivalent network.

## VITA

Shih-Pai Tung was born on February 14, 1920, in Mukden, China. He entered the Hangchow Christian University in 1938 and received the degree of Bachelor of Science in Civil Engineering in 1942. In 1943, he joined the National South-West Associated University and received the degree of Bachelor of Science in Electrical Engineering in 1946 and worked as an assistant in the National Tsing-Hua University for two years before he came to this University in 1948. He held a University Fellowship in the academic year 1950-51 and is a member of Sigma Xi.

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